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**VIA E-MAIL**: Robinson.Jeffery@epa.gov

August 30, 2018

Mr. Jeff Robinson
Air Permits Section Chief
Environmental Protection Agency, Region 6
1445 Ross Avenue, Suite 1200
Dallas, TX 75202-2733

*Re: TGTI Initial Response to NSR Air Permit Completeness Determination - Questions 1, 4, 6, 8, 9, 10*

Dear Mr. Robinson:

Texas Gulf Terminals Inc. (TGTI) submitted a New Source Review (NSR) Air Permit Application as part of the TGTI project to obtain a license for the operation of a Deepwater Port (DWP) in Federal waters of the U.S. Gulf of Mexico. On August 10, 2018, TGTI received a letter from Environmental Protection Agency (EPA) requesting additional information to support the NSR Permit Application Completeness Review. TGTI's responses to EPA's questions are provided in this letter.

The following attachments are provided in support of TGTI's responses to the request for additional information:

Attachment 1 – TGTI Crude Composition Data
Attachment 2 – Detailed Emission Calculations for Crude Vapor Speciation
Attachment 3 – GHG Emissions Calculation for Marine Loading and SPM Fugitives
Attachment 4 – Comparison of Crude/Condensate Emissions between Equations 1 and 2 of AP-42 Chapter 5.2
Attachment 5 – Reference for Equation 3 of AP-42 Chapter 5.2

The responses below are numbered corresponding to the questions in the August 10, 2018 letter. This letter answers questions 1, 4, 6, 8, 9, and 10 of the letter. TGTI is in the process of compiling the information necessary to respond to Questions 2, 3, 5, and 7 and will submit a separate letter in response to the questions not answered in this letter.

## EPA Question 1

*Please provide additional supporting technical documentation to allow for the verification of the basis for the emission calculations. Specifically, we are requesting data regarding the true vapor pressure of the crude oil (psia), molecular weight of vapors (lb/lb-mole), material composition data of the associated emissions (speciated) for the crude oil/condensate proposed to be used for the export operation.*

*TGTI Response:*
The crude composition data obtained from TGTI is provided in Attachment 1. Detailed emission calculations for crude vapor speciation are provided in Attachment 2. The speciated vapor weight percentages are calculated based on Raoult's law and are detailed in the TGTI's response to Question No. 10 below.

As a conservative assumption, the properties of gasoline were used to represent condensate in the hourly and annual emission calculations. As shown in Attachment 1, the maximum reid vapor pressure (RVP) of crude from the crude profiles in 8.8 psia. The annual emissions from condensate are conservatively based on an annual average RVP of 13.5 psia, which is equivalent to a TVP of 9.25 psia. A maximum true vapor pressure (TVP) of 11 psia is used to calculate hourly emissions from condensate. For crude oil, the hourly and annual emissions are based on a maximum TVP of 11 psia and an annual average TVP of 11 psia. The TVP values used in the calculations are conservative because the TVP of crude is dependent on temperature and will not always be at the maximum vapor pressure.

Different molecular weights for the hourly and annual condensate emissions are used because the molecular weight of gasoline (which is used to represent condensate) varies with vapor pressure. Different RVP gasolines have different molecular weights. This is consistent with Table 7.1-2 of AP-42 Chapter 7.1, where the molecular weight of gasoline ranges from 60 – 68 lb/lb-mole for gasoline RVPs ranging from 7 – 15 psia.

## EPA Question 4

*On page 9-5 of the PSD permit application, TGTI asserts that the SPM buoy operation will comply with all applicable requirements in 30 TAC 111, Control of Air Pollution from Visible Emissions and Particulate Matter. For the permitting record, please specify, if possible, the specific provisions in 30 TAC 111 that TGTI is proposing to comply with meet and the associated method of compliance and/or monitoring to assure continuous compliance.*

*TGTI Response:*
The proposed SPM buoy system will comply with 30 TAC §111 requirements for visible emissions from the proposed operations. The nature of the emissions generated by the proposed SPM buoy system are the exhaust of organic vapors through the loading of the marine vessel tanks. The proposed SPM buoy system will not emit particular matter emissions nor visible emissions through the loading of the marine vessel tanks. Therefore, it is not a reasonable expectation that there will be visible emissions from the operation of the proposed SPM buoy system. As such, TGTI proposes that the inherent nature of emissions from the process are sufficient to provide reasonable assurance that the SPM buoy will remain in continuous compliance with the applicable provisions of 30 TAC §111.

## EPA Question 6

*Please provide your calculations for Greenhouse Gas (GHG) emissions from the SPM buoy and marine loading operation based on the gas speciation analysis from the crude/condensate to be exported. If the resulting GHG emissions level is equal to or greater than 75,000 tpy of CO2e, a five-step BACT analysis for GHG emissions associated with marine loading operations will be needed. [40 CFR 52.21(b)(49)(iv)(a)].*

*TGTI Response:*
Based on the crude composition data obtained from TGTI, the calculated average vapor weight percent for methane and ethane combined is 26%. The methane and ethane combined weight percentage is used to conservatively estimate the annual methane emissions from the SPM buoy and marine loading operations. The resulting methane emissions estimate is multiplied by the methane global warming potential (GWP) of 25 based on Appendix A, Table A-1 of 40 CFR Part 98 to obtain the conservative estimate of $CO_2e$ emissions. As shown in the detailed emissions calculations provided in Attachment 3, the estimated GHG emissions from the SPM buoy and marine loading operation will be less than 75,000 tpy of $CO_2e$.

## EPA Question 8

*The calculations for the hourly and annual VOC emission calculations rely on U.S. EPA AP-42 emission factors, Section 5.2 (7/08), Table 5.2-1, equation 1. The footnote to Table 5.2-1 states that equations 2 and 3 should be used to estimate emissions from marine loading operation of crude oil -not equation 1. Please provide additional information to support the use of equation 1 to determine the Saturation Factor rather than equations 2 and 3.*

*TGTI Response:*
The use of Equation 1 and saturation factor from Table 5.2-1 provides the worst-case emissions from the proposed source. A comparison of crude oil and condensate loading emissions between Equations 1 and 2 is provided in Attachment 4.

Additionally, TGTI reviewed the equations EPA suggested and determined them not to be applicable for estimating emissions from the loading of very large crude carriers (VLCCs). The reference that EPA cites for Equation 3 in AP-42 Chapter 5.2, (provided as Attachment 5) "*Atmospheric Hydrocarbon Emissions From Marine Vessel Transfer Operations, Publication 2514A, American Petroleum Institute, Washington, DC, 2009*" states that the derived equation should not be used to estimate evaporative losses from VLCCs or ultra large crude carriers (ULCCs) unless the saturation factor $K_S$ is determined. Further, TCEQ has requested the use of Equation 1 over Equation 2/3 in recent permitting actions.

## EPA Question 9

*In comparing the calculations for the hourly and annual VOC emission calculations, it is unclear why different condensate physical properties were used in the calculations. For example: Hourly Condensate Vapor MW = 60 lb/lb-mol and the Annual Condensate Loading MW = 62 lb/lb-mol. Differences may also be found in the Maximum True Vapor Pressure (TVP). Please provide any technical details on why different condensate physical properties were used in the calculations.*

*TGTI Response:*
The properties of gasoline were used to represent condensate in the hourly and annual emission calculations. A maximum TVP of 11 psia is used to calculate hourly emissions from condensate. The annual emissions from condensate are based on an annual average RVP of 13.5 psia, which is equivalent to a TVP of 9.25 psia. For crude oil, the hourly and annual emissions are based on a maximum TVP of 11 psia and an annual average TVP of 11 psia. The TVP values used in the calculations are based on conservative assumptions.

Different molecular weights for the hourly and annual condensate emissions are used because the molecular weight of gasoline (which is used to represent condensate) varies with vapor pressure. Different RVP gasolines have different molecular weights. This is consistent with Table 7.1-2 of AP-42 Chapter 7.1, where the molecular weight of gasoline ranges from 60 – 68 lb/lb-mole for gasoline RVPs ranging from 7 – 15 psia.

## EPA Question 10

*Please provide additional information related to the mixture representation used in the TANKS 4.09d program for condensate and how this information correlates with the HAP speciation profile.*

*TGTI Response:*
The crude composition data obtained from TGTI is provided in Attachment 1. Benzene and toluene are the

two HAPs identified from these profiles. A summary of HAP speciation obtained from the crude profiles is shown in Table 1 below.

**Table 1. TGTI Crude Assays HAP Speciation (Liquid wt%)**

| Profiles | Benzene | Toluene |
|---|---|---|
| **1** | 0.22 | 0.61 |
| **2** | 0.65 | 2.74 |
| **3** | 0.76 | 0.32 |
| **4** | 0.15 | 1.37 |
| **5** | 0.24 | 0.47 |

The speciated vapor weight percentages are calculated based on the following steps.

First, liquid mole fraction ($l_i$) is calculated using the maximum liquid weight percent ($W_i$) from the crude profiles provided in Attachment 1 using the following equation.

$$l_i = (W_i / M_i) / \mathbf{\Sigma} (W_i / M_i)$$

where $l_i$ = liquid mole fraction of component i
$M_i$ = liquid molecular weight of component i, lb/lbmol
$W_i$ = liquid weight percent of component i

Second, partial pressure of the individual components is estimated using Raoult's law. According to Raoult's Law, the partial pressure of a component is the product of its pure component vapor pressure and its liquid mole fraction. The sum of the partial pressures is equal to the total vapor pressure of the mixture.

The pure component vapor pressures are calculated using the Antoine's equation.

$$\text{Log } P = A - B / (T + C)$$

where P = vapor pressure, mmHg
T = temperature, °C
A, B, and C = component-specific constants

Using the Antoine's coefficients for benzene as an example, A = 6.905, B = 1211.033 and C = 220.790, the pure component vapor pressure comes out to be 1.68 psia at 23 °C. In order to calculate the mixture vapor pressure, the partial pressures need to be calculated for each component. The partial pressure is the product of the pure component vapor pressure of each component (calculated above) and the mole fraction of each component in the liquid as calculated in step 1.

Third, the vapor mole fractions of the components are calculated. The vapor mole fraction, $y_i$, is equal to the partial pressure of the component divided by the total partial pressure of the mixture.

$$y_i = P_{partial} / P_{total}$$

where $y_i$ = vapor mole fraction of component i
$P_{partial}$ = partial pressure of component i

$P_{total}$ = total partial pressure of the mixture

Fourth, the molecular weight of the vapor, $M_V$ is calculated. Molecular weight of the vapor depends upon the mole fractions of the individual components in the vapor.

$$M_{Vi} = \Sigma M_i y_i$$

where $M_{vi}$ = vapor molecular weight of component i
$M_i$ = liquid molecular weight of component i
$y_i$ = vapor mole fraction of component i

Finally, vapor weight fraction ($W_i$) of the component is the product of the molecular weight of the component ($M_i$) and vapor mole fraction ($y_i$) divided by the summation of the products of the molecular weight of the components and their vapor mole fractions.

$$W_i = M_i y_i / \Sigma M_i y_i$$

Based on the approach explained above, the average vapor weight fractions of components in the crude profiles at 73.5 °F are calculated and the maximum HAP vapor speciation is summarized below. Detailed emission calculations for vapor speciation are provided in Attachment 2.

**Table 2. HAP Speciation based on Crude profiles provided by TGTI**

| HAP | Max Single HAP Vapor wt% | Max Total HAP Vapor wt% |
|---|---|---|
| Benzene | 0.24% | 0.53% |
| Toluene | 0.30% | |

A conservative approach was employed that assumed benzene and toluene were the only components present in the crude and by applying a 100% safety factor to the benzene and toluene liquid weight fraction from the TGTI crude profiles. The resulting vapor weight fractions for benzene and toluene used in the DWP license application are summarized in Table 3 below. Please note that the HAP vapor weight percentages used in the DWP application (Table 3) are conservative since they are significantly higher than the HAP vapor weight fractions calculated based on the TGTI crude profiles (Table 2).

**Table 3. HAP Speciation used in the Application**

| HAP | Max Single HAP Vapor wt% | Max Total HAP Vapor wt% |
|---|---|---|
| Benzene | 0.95% | 1.93% |
| Toluene | 0.98% | |

If you have any questions, comments, or need additional information, do not hesitate to contact me at (972) 661-8100 or Denise Rogers at (832) 203-6493.

Sincerely,

TRINITY CONSULTANTS

Brian Burdorf
Director

cc: Denise Rogers, Compliance Manager - TGTI

# ATTACHMENT 1 – TGTI CRUDE COMPOSITION DATA

Reference: **Crude 1**
Crude: **Crude 1**

# Crude Summary Report

| General Information | | Molecules (%wt on crude) | | Whole Crude Properties | |
|---|---|---|---|---|---|
| Reference: | Crude 1 | methane + ethane | 0.02 | Density @ 15°C (g/cc) | 0.817 |
| Name: | Crude 1 | propane | 0.21 | API Gravity | 41.60 |
| Traded Crude: | Unknown | isobutane | 0.20 | Total Sulphur (% wt) | 0.25 |
| Origin: | United States of A | n-butane | 1.15 | Pour Point (°C) | -26.39 |
| Sample Date: | - | isopentane | 1.18 | Viscosity @ 20°C (cSt) | 8.82 |
| Assay Date: | - | n-pentane | 1.70 | Viscosity @ 40°C (cSt) | 4.89 |
| Issue Date: | - | cyclopentane | 0.08 | Nickel (ppm) | 0.5 |
| Comments: | - | $C_6$ paraffins | 1.06 | Vanadium (ppm) | 1.0 |
| | | $C_6$ naphthenes | 0.24 | Total Nitrogen (ppm) | 177 |
| | | benzene | 0.22 | Total Acid Number (mgKOH/g) | 0.03 |
| | | $C_7$ paraffins | 2.21 | Mercaptan Sulphur (ppm) | 20.3 |
| | | $C_7$ naphthenes | 0.87 | Hydrogen Sulphide (ppm) | 0.0 |
| | | toluene | 0.61 | Reid Vapour Pressure (psi) | 8.8 |

| Cut Data | | Atmospheric Cuts | | | | | | | | | Vacuum Cuts | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Start (°C) | IBP | C5 | 65 | 100 | 150 | 200 | 250 | 300 | 350 | 370 | 370 | 450 | 500 | 550 |
| End (°C) | FBP | 65 | 100 | 150 | 200 | 250 | 300 | 350 | 370 | FBP | 450 | 500 | 550 | FBP |
| Yield (% wt) | | 3.9 | 3.4 | 9.5 | 9.3 | 9.9 | 9.9 | 9.5 | 3.6 | 39.5 | 13.5 | 7.5 | 6.5 | 11.9 |
| Yield (% vol) | | 4.9 | 3.9 | 10.4 | 9.9 | 10.1 | 9.8 | 9.2 | 3.5 | 36.0 | 12.8 | 6.9 | 5.9 | 10.4 |
| Cumulative Yield (% wt) | | 1.6 | 5.4 | 8.8 | 18.4 | 27.7 | 37.6 | 47.5 | 56.9 | 60.5 | 60.5 | 74.1 | 81.5 | 88.1 |
| Volume Average B.P. (°C) | 308 | 39 | 91 | 128 | 175 | 225 | 275 | 325 | 360 | 500 | 409 | 474 | 524 | 616 |
| Density @ 15°C (g/cc) | 0.817 | 0.638 | 0.714 | 0.748 | 0.768 | 0.797 | 0.823 | 0.842 | 0.852 | 0.896 | 0.866 | 0.887 | 0.902 | 0.936 |
| API Gravity | 41.6 | 90.2 | 66.7 | 57.6 | 52.7 | 45.9 | 40.4 | 36.4 | 34.6 | 26.3 | 31.9 | 28.0 | 25.3 | 19.5 |
| UOPK | 12.4 | | | 12.0 | 12.1 | 12.1 | 12.1 | 12.2 | 12.3 | 12.5 | 12.4 | 12.4 | 12.5 | 12.5 |
| Molecular Weight (g/mol) | | | | 117 | 149 | 184 | 224 | 271 | 309 | 460 | 364 | 446 | 511 | 627 |
| Total Sulphur (% wt) | 0.247 | 0.002 | 0.005 | 0.008 | 0.016 | 0.040 | 0.098 | 0.202 | 0.275 | 0.51 | 0.345 | 0.444 | 0.54 | 0.73 |
| Mercaptan Sulphur (ppm) | 20.3 | 2.1 | 15.8 | 22.0 | 27.8 | 26.8 | 18.8 | | | | | | | |
| Total Nitrogen (ppm) | 177 | | | | | 2 | 4 | 15 | 35 | 441 | 112 | 310 | 512 | 858 |
| Basic Nitrogen (ppm) | 119.61 | | | | | 0.7042 | 2.7875 | 8.4895 | 15.961 | 298.61 | 38.448 | 100.68 | 201.42 | 770.76 |
| Total Acid Number (mgKOH/g) | 0.03 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.02 | 0.04 | 0.04 | 0.06 | 0.06 | 0.07 | 0.07 | 0.06 |
| Viscosity @ 20°C (cSt) | 8.82 | | | | 2.47 | | | | | | | | | |
| Viscosity @ 40°C (cSt) | 4.89 | | | | 1.74 | 2.69 | 4.36 | 7.58 | 11.8 | | | | | |
| Viscosity @ 50°C (cSt) | 3.82 | | | | | 2.25 | 3.55 | 5.90 | 8.81 | 90.2 | 16.5 | 47.2 | 140 | |
| Viscosity @ 60°C (cSt) | | | | | | | | | | 56.4 | 12.2 | 31.4 | 83.6 | |
| Viscosity @ 100°C (cSt) | | | | | | | | | | 13.9 | 4.65 | 9.24 | 18.3 | 114 |
| Viscosity @ 130°C (cSt) | | | | | | | | | | | | | | 35.7 |
| RON (Clear) | 24.9 | 77.7 | 51.0 | 52.6 | 39.0 | | | | | | | | | |
| MON (Clear) | 36.8 | 77.2 | 50.2 | 48.5 | 37.1 | | | | | | | | | |
| Paraffins (% wt) | 41.6 | 97.9 | 70.0 | 57.6 | 46.1 | | | | | | | | | |
| Naphthenes (%wt) | 35.1 | 2.1 | 23.6 | 25.5 | 30.9 | | | | | | | | | |
| Aromatics (% wt) | 23.3 | 0.0 | 6.4 | 16.9 | 23.1 | | | | | | | | | |
| Pour Point (°C) | -26 | | | | | -45 | -22 | 1 | 12 | 15 | 28 | 43 | 51 | 26 |
| Cloud Point (°C) | | | | | | -42 | -20 | 3 | | | | | | |
| Freeze Point (°C) | | | | | -61 | -39 | -16 | | | | | | | |
| Smoke Point (mm) | | | | | 27 | 21 | 16 | | | | | | | |
| Cetane Index | | | | | 50 | 56 | 62 | 70 | 77 | | | | | |
| Naphthalenes (% vol) | | | | | 0.0839 | 2.2615 | 7.2394 | 12.325 | | | | | | |
| Aniline Point (°C) | | | | 48.5 | 54.8 | 64.9 | 74.8 | 84.6 | 91.4 | | 100.9 | 111.6 | 118.0 | |
| Hydrogen (% wt) | | 16.6 | 15.2 | 14.5 | 14.4 | 13.9 | 13.5 | 13.2 | 13.1 | | 12.9 | 12.8 | 12.7 | |
| Wax (% wt) | 10.7 | | | | | | | | | 19.6 | 23.5 | 24.6 | 21.1 | 11.2 |
| $C_7$ Asphaltenes (% wt) | 0.1 | | | | | | | | | 0.2 | | 0.0 | 0.0 | 0.6 |
| Micro Carbon Residue (% wt) | 0.4 | | | | | | | | | 1.0 | | 0.1 | 0.6 | 2.8 |
| Rams. Carbon Residue (% wt) | 0.3 | | | | | | | | | 0.9 | | 0.1 | 0.5 | 2.5 |
| Vanadium (ppm) | 1.0 | | | | | | | | | 2.6 | | 0.0 | 0.0 | 8.5 |
| Nickel (ppm) | 0.5 | | | | | | | | | 1.3 | | 0.0 | 0.0 | 4.4 |
| Iron (ppm) | 51.0 | | | | | | | | | 129.2 | | 0.0 | 0.0 | 427.3 |

Reference: **Crude 2**
Crude: **Crude 2**

# Crude Summary Report

| General Information | | Molecules (%wt on crude) | | Whole Crude Properties | |
|---|---|---|---|---|---|
| Reference: | Crude 2 | methane + ethane | 0.00 | Density @ 15°C (g/cc) | 0.735 |
| Name: | Crude 2 | propane | 0.52 | API Gravity | 60.88 |
| Traded Crude: | Unknown | isobutane | 0.83 | Total Sulphur (% wt) | 0.01 |
| Origin: | Unknown | n-butane | 1.89 | Pour Point (°C) | -19.71 |
| Sample Date: | 12 May 2017 | isopentane | 2.36 | Viscosity @ 20°C (cSt) | 1.05 |
| Assay Date: | 18 May 2017 | n-pentane | 3.38 | Viscosity @ 40°C (cSt) | 0.81 |
| Issue Date: | - | cyclopentane | 0.00 | Nickel (ppm) | 0.0 |
| Comments: | - | $C_6$ paraffins | 3.64 | Vanadium (ppm) | 0.0 |
| | | $C_6$ naphthenes | 6.54 | Total Nitrogen (ppm) | 7 |
| | | benzene | 0.65 | Total Acid Number (mgKOH/g) | 0.03 |
| | | $C_7$ paraffins | 8.02 | Mercaptan Sulphur (ppm) | 8.0 |
| | | $C_7$ naphthenes | 5.14 | Hydrogen Sulphide (ppm) | 0.0 |
| | | toluene | 2.74 | Reid Vapour Pressure (psi) | 8.0 |

| Cut Data | | Atmospheric Cuts | | | | | | | | | Vacuum Cuts | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Start (°C) | IBP | C5 | 65 | 100 | 150 | 200 | 250 | 300 | 350 | 370 | 370 | 450 | 500 | 550 |
| End (°C) | FBP | 65 | 100 | 150 | 200 | 250 | 300 | 350 | 370 | FBP | 450 | 500 | 550 | FBP |
| Yield (% wt) | | 7.4 | 19.4 | 27.1 | 15.2 | 9.8 | 6.8 | 4.6 | 1.4 | 5.0 | 3.4 | 0.9 | 0.4 | 0.3 |
| Yield (% vol) | | 8.5 | 19.7 | 26.7 | 15.2 | 9.5 | 6.4 | 4.2 | 1.2 | 4.3 | 2.9 | 0.8 | 0.4 | 0.2 |
| Cumulative Yield (% wt) | | 3.3 | 10.7 | 30.0 | 57.2 | 72.3 | 82.2 | 89.0 | 93.6 | 95.0 | 95.0 | 98.4 | 99.3 | 99.7 |
| Volume Average B.P. (°C) | 154 | 39 | 85 | 123 | 173 | 224 | 273 | 323 | 360 | 436 | 404 | 472 | 522 | 596 |
| Density @ 15°C (g/cc) | 0.735 | 0.636 | 0.723 | 0.747 | 0.731 | 0.762 | 0.788 | 0.810 | 0.826 | 0.860 | 0.845 | 0.877 | 0.902 | 0.944 |
| API Gravity | 60.9 | 91.1 | 64.1 | 57.9 | 61.9 | 54.1 | 48.1 | 43.0 | 39.8 | 32.9 | 36.0 | 29.8 | 25.2 | 18.3 |
| UOPK | 12.5 | | | 12.0 | 12.7 | 12.6 | 12.6 | 12.6 | 12.6 | 12.6 | 12.6 | 12.6 | 12.5 | 12.3 |
| Molecular Weight (g/mol) | | | | 113 | 151 | 187 | 228 | 276 | 315 | 396 | 364 | 446 | 507 | 593 |
| Total Sulphur (% wt) | 0.010 | 0.000 | 0.001 | 0.002 | 0.003 | 0.007 | 0.015 | 0.031 | 0.049 | 0.105 | 0.077 | 0.129 | 0.175 | 0.248 |
| Mercaptan Sulphur (ppm) | 8.0 | 1.4 | 7.1 | 8.3 | 9.0 | 7.9 | 5.6 | | | | | | | |
| Total Nitrogen (ppm) | 7 | | | | | 3 | 8 | 13 | 19 | 112 | 46 | 130 | 242 | 625 |
| Basic Nitrogen (ppm) | 4.523 | | | | | 1.0709 | 3.6077 | 9.0155 | 15.216 | 69.956 | 27.152 | 60.412 | 117.89 | 525.24 |
| Total Acid Number (mgKOH/g) | 0.03 | 0.00 | 0.00 | 0.01 | 0.01 | 0.02 | 0.04 | 0.05 | 0.06 | 0.07 | 0.07 | 0.08 | 0.07 | 0.06 |
| Viscosity @ 20°C (cSt) | 1.05 | | | | 1.53 | | | | | | | | | |
| Viscosity @ 40°C (cSt) | 0.81 | | | | 1.13 | 1.81 | 3.06 | 5.41 | 8.71 | | | | | |
| Viscosity @ 50°C (cSt) | 0.73 | | | | | 1.56 | 2.55 | 4.35 | 6.72 | 22.0 | 12.4 | 43.2 | 156 | |
| Viscosity @ 60°C (cSt) | | | | | | | | | | 15.9 | 9.32 | 29.2 | 92.8 | |
| Viscosity @ 100°C (cSt) | | | | | | | | | | 5.74 | 3.90 | 8.90 | 20.0 | 114 |
| Viscosity @ 130°C (cSt) | | | | | | | | | | | | | | 36.2 |
| RON (Clear) | 50.7 | 76.7 | 61.4 | 59.5 | 38.5 | | | | | | | | | |
| MON (Clear) | 51.1 | 76.5 | 58.9 | 56.3 | 36.8 | | | | | | | | | |
| Paraffins (% wt) | 52.8 | 100.0 | 51.8 | 53.3 | 49.2 | | | | | | | | | |
| Naphthenes (%wt) | 29.8 | 0.0 | 44.8 | 25.4 | 26.5 | | | | | | | | | |
| Aromatics (% wt) | 17.4 | 0.0 | 3.4 | 21.3 | 24.3 | | | | | | | | | |
| Pour Point (°C) | -20 | | | | | -41 | -16 | 8 | 20 | 39 | 33 | 46 | 53 | -4 |
| Cloud Point (°C) | | | | | | -38 | -14 | 10 | | | | | | |
| Freeze Point (°C) | | | | | -61 | -36 | -11 | | | | | | | |
| Smoke Point (mm) | | | | | 28 | 24 | 20 | | | | | | | |
| Cetane Index | | | | | 72 | 77 | 83 | 88 | 94 | | | | | |
| Naphthalenes (% vol) | | | | | 0.176 | 1.336 | 3.5329 | 5.7802 | | | | | | |
| Aniline Point (°C) | | | | 46.6 | 53.1 | 65.1 | 76.7 | 87.8 | 95.3 | | 103.5 | 113.9 | 119.5 | |
| Hydrogen (% wt) | | 16.7 | 15.1 | 14.1 | 14.2 | 13.7 | 13.4 | 13.3 | 13.2 | | 13.3 | 13.2 | 13.1 | |
| Wax (% wt) | 3.5 | | | | | | | | | 27.0 | 28.0 | 28.4 | 24.4 | 15.3 |
| $C_7$ Asphaltenes (% wt) | 0.0 | | | | | | | | | 0.1 | | 0.0 | 0.0 | 1.2 |
| Micro Carbon Residue (% wt) | 0.0 | | | | | | | | | 0.5 | | 0.3 | 1.6 | 6.1 |
| Rams. Carbon Residue (% wt) | 0.0 | | | | | | | | | 0.5 | | 0.2 | 1.5 | 5.6 |
| Vanadium (ppm) | 0.0 | | | | | | | | | 0.2 | | 0.0 | 0.0 | 3.1 |
| Nickel (ppm) | 0.0 | | | | | | | | | 0.5 | | 0.0 | 0.0 | 8.8 |
| Iron (ppm) | 2.2 | | | | | | | | | 43.9 | | 0.0 | 0.0 | 760.6 |

Reference: **Crude 3**
Crude: **Crude 3**

# Crude Summary Report

| General Information | | Molecules (%wt on crude) | | Whole Crude Properties | |
|---|---|---|---|---|---|
| Reference: | Crude 3 | methane + ethane | 0.03 | Density @ 15°C (g/cc) | 0.811 |
| Name: | Crude 3 | propane | 0.41 | API Gravity | 42.89 |
| Traded Crude: | Unknown | isobutane | 0.25 | Total Sulphur (% wt) | 0.16 |
| Origin: | United States of A | n-butane | 1.27 | Pour Point (°C) | -23.84 |
| Sample Date: | - | isopentane | 1.08 | Viscosity @ 20°C (cSt) | 5.29 |
| Assay Date: | - | n-pentane | 1.63 | Viscosity @ 40°C (cSt) | 3.27 |
| Issue Date: | - | cyclopentane | 0.05 | Nickel (ppm) | 1.5 |
| Comments: | - | $C_6$ paraffins | 1.88 | Vanadium (ppm) | 1.7 |
| | | $C_6$ naphthenes | 2.95 | Total Nitrogen (ppm) | 298 |
| | | benzene | 0.76 | Total Acid Number (mgKOH/g) | 0.03 |
| | | $C_7$ paraffins | 3.68 | Mercaptan Sulphur (ppm) | 77.0 |
| | | $C_7$ naphthenes | 2.05 | Hydrogen Sulphide (ppm) | 0.0 |
| | | toluene | 0.32 | Reid Vapour Pressure (psi) | 6.7 |

| Cut Data | | Atmospheric Cuts | | | | | | | | | Vacuum Cuts | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Start (°C) | IBP | C5 | 65 | 100 | 150 | 200 | 250 | 300 | 350 | 370 | 370 | 450 | 500 | 550 |
| End (°C) | FBP | 65 | 100 | 150 | 200 | 250 | 300 | 350 | 370 | FBP | 450 | 500 | 550 | FBP |
| Yield (% wt) | | 3.9 | 9.3 | 10.7 | 8.8 | 9.1 | 8.7 | 8.0 | 3.0 | 36.5 | 11.0 | 5.6 | 4.3 | 15.6 |
| Yield (% vol) | | 4.9 | 10.3 | 11.6 | 9.3 | 9.3 | 8.5 | 7.7 | 2.9 | 32.5 | 10.2 | 5.1 | 3.9 | 13.3 |
| Cumulative Yield (% wt) | | 2.0 | 5.9 | 15.2 | 25.9 | 34.7 | 43.8 | 52.5 | 60.5 | 63.5 | 63.5 | 74.5 | 80.1 | 84.4 |
| Volume Average B.P. (°C) | 304 | 41 | 85 | 125 | 175 | 225 | 275 | 325 | 360 | 563 | 409 | 474 | 524 | 727 |
| Density @ 15°C (g/cc) | 0.811 | 0.639 | 0.733 | 0.743 | 0.768 | 0.797 | 0.821 | 0.842 | 0.854 | 0.911 | 0.870 | 0.889 | 0.896 | 0.955 |
| API Gravity | 42.9 | 89.8 | 61.5 | 59.0 | 52.8 | 46.0 | 40.7 | 36.5 | 34.0 | 23.8 | 31.0 | 27.5 | 26.3 | 16.6 |
| UOPK | 12.5 | | | 12.1 | 12.1 | 12.1 | 12.1 | 12.2 | 12.2 | 12.6 | 12.3 | 12.4 | 12.6 | 12.7 |
| Molecular Weight (g/mol) | | | | 115 | 149 | 184 | 224 | 271 | 308 | 508 | 362 | 444 | 513 | 762 |
| Total Sulphur (% wt) | 0.162 | 0.002 | 0.003 | 0.005 | 0.010 | 0.025 | 0.062 | 0.134 | 0.188 | 0.373 | 0.244 | 0.314 | 0.365 | 0.487 |
| Mercaptan Sulphur (ppm) | 77.0 | 9.9 | 69.3 | 108.4 | 134.5 | 117.5 | 70.9 | | | | | | | |
| Total Nitrogen (ppm) | 298 | | | | | 2 | 7 | 29 | 66 | 803 | 197 | 517 | 838 | 1321 |
| Basic Nitrogen (ppm) | 165.3 | | | | | 0.8954 | 4.1393 | 13.634 | 26.062 | 446.08 | 58.147 | 144.05 | 263.67 | 876.91 |
| Total Acid Number (mgKOH/g) | 0.03 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.02 | 0.04 | 0.05 | 0.05 | 0.06 | 0.07 | 0.07 | 0.04 |
| Viscosity @ 20°C (cSt) | 5.29 | | | | 2.49 | | | | | | | | | |
| Viscosity @ 40°C (cSt) | 3.27 | | | | 1.74 | 2.70 | 4.43 | 7.86 | 12.5 | | | | | |
| Viscosity @ 50°C (cSt) | 2.67 | | | | | 2.25 | 3.59 | 6.07 | 9.20 | 237 | 17.4 | 47.0 | 110 | |
| Viscosity @ 60°C (cSt) | | | | | | | | | | 132 | 12.7 | 31.1 | 66.8 | |
| Viscosity @ 100°C (cSt) | | | | | | | | | | 24.2 | 4.71 | 8.94 | 15.2 | 373 |
| Viscosity @ 130°C (cSt) | | | | | | | | | | | | | | 85.0 |
| RON (Clear) | 28.3 | 77.3 | 66.8 | 52.2 | 39.0 | | | | | | | | | |
| MON (Clear) | 42.7 | 77.0 | 63.9 | 49.9 | 37.1 | | | | | | | | | |
| Paraffins (% wt) | 42.4 | 98.7 | 47.5 | 61.5 | 46.5 | | | | | | | | | |
| Naphthenes (%wt) | 35.6 | 1.3 | 44.4 | 26.3 | 30.6 | | | | | | | | | |
| Aromatics (% wt) | 22.0 | 0.0 | 8.1 | 12.1 | 22.9 | | | | | | | | | |
| Pour Point (°C) | -24 | | | | | -44 | -21 | 3 | 15 | 13 | 30 | 45 | 52 | 5 |
| Cloud Point (°C) | | | | | | -42 | -19 | 4 | | | | | | |
| Freeze Point (°C) | | | | | -60 | -37 | -14 | | | | | | | |
| Smoke Point (mm) | | | | | 27 | 21 | 16 | | | | | | | |
| Cetane Index | | | | | 50 | 56 | 63 | 70 | 76 | | | | | |
| Naphthalenes (% vol) | | | | | 0.0423 | 1.3678 | 5.5322 | 10.193 | | | | | | |
| Aniline Point (°C) | | | | 49.2 | 55.8 | 66.0 | 76.1 | 86.1 | 93.0 | | 102.5 | 113.4 | 119.6 | |
| Hydrogen (% wt) | | 16.6 | 14.7 | 14.7 | 14.4 | 13.9 | 13.5 | 13.3 | 13.1 | | 12.9 | 12.7 | 12.5 | |
| Wax (% wt) | 9.1 | | | | | | | | | 18.3 | 24.3 | 25.1 | 23.5 | 10.1 |
| $C_7$ Asphaltenes (% wt) | 0.2 | | | | | | | | | 0.6 | | 0.0 | 0.0 | 1.4 |
| Micro Carbon Residue (% wt) | 0.7 | | | | | | | | | 1.8 | | 0.1 | 0.6 | 4.1 |
| Rams. Carbon Residue (% wt) | 0.6 | | | | | | | | | 1.7 | | 0.1 | 0.5 | 3.7 |
| Vanadium (ppm) | 1.7 | | | | | | | | | 4.6 | | 0.0 | 0.0 | 10.8 |
| Nickel (ppm) | 1.5 | | | | | | | | | 4.0 | | 0.0 | 0.0 | 9.4 |
| Iron (ppm) | 24.0 | | | | | | | | | 65.7 | | 0.0 | 0.0 | 153.4 |

Reference: **Crude 4**
Crude: **Crude 4**

# Crude Summary Report

| General Information | | Molecules (%wt on crude) | | Whole Crude Properties | |
|---|---|---|---|---|---|
| Reference: | Crude 4 | methane + ethane | 0.02 | Density @ 15°C (g/cc) | 0.822 |
| Name: | Crude 4 | propane | 0.43 | API Gravity | 40.60 |
| Traded Crude: | Unknown | isobutane | 0.39 | Total Sulphur (% wt) | 0.56 |
| Origin: | Unknown | n-butane | 1.49 | Pour Point (°C) | -18.48 |
| Sample Date: | 05 March 2016 | isopentane | 1.08 | Viscosity @ 20°C (cSt) | 4.88 |
| Assay Date: | 07 March 2016 | n-pentane | 1.67 | Viscosity @ 40°C (cSt) | 3.31 |
| Issue Date: | - | cyclopentane | 0.22 | Nickel (ppm) | 5.6 |
| Comments: | - | $C_6$ paraffins | 2.83 | Vanadium (ppm) | 18.6 |
| | | $C_6$ naphthenes | 2.81 | Total Nitrogen (ppm) | 953 |
| | | benzene | 0.15 | Total Acid Number (mgKOH/g) | 0.05 |
| | | $C_7$ paraffins | 3.74 | Mercaptan Sulphur (ppm) | 1.6 |
| | | $C_7$ naphthenes | 2.24 | Hydrogen Sulphide (ppm) | 0.0 |
| | | toluene | 1.37 | Reid Vapour Pressure (psi) | 7.7 |

| Cut Data | | Atmospheric Cuts | | | | | | | | | Vacuum Cuts | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Start (°C) | IBP | C5 | 65 | 100 | 150 | 200 | 250 | 300 | 350 | 370 | 370 | 450 | 500 | 550 |
| End (°C) | FBP | 65 | 100 | 150 | 200 | 250 | 300 | 350 | 370 | FBP | 450 | 500 | 550 | FBP |
| Yield (% wt) | | 4.8 | 8.5 | 11.7 | 8.7 | 9.4 | 9.0 | 8.2 | 3.0 | 34.3 | 10.6 | 5.6 | 4.8 | 13.3 |
| Yield (% vol) | | 6.1 | 9.8 | 12.5 | 9.2 | 9.5 | 8.9 | 7.8 | 2.8 | 29.8 | 9.8 | 5.0 | 4.2 | 10.8 |
| Cumulative Yield (% wt) | | 2.4 | 7.1 | 15.7 | 27.4 | 36.1 | 45.5 | 54.5 | 62.7 | 65.7 | 65.7 | 76.3 | 81.9 | 86.7 |
| Volume Average B.P. (°C) | 281 | 44 | 84 | 124 | 175 | 225 | 275 | 324 | 360 | 528 | 408 | 474 | 524 | 662 |
| Density @ 15°C (g/cc) | 0.822 | 0.645 | 0.717 | 0.765 | 0.779 | 0.811 | 0.835 | 0.857 | 0.872 | 0.944 | 0.891 | 0.917 | 0.939 | 1.008 |
| API Gravity | 40.6 | 87.8 | 65.8 | 53.3 | 50.1 | 42.9 | 37.8 | 33.5 | 30.8 | 18.3 | 27.3 | 22.7 | 19.2 | 8.8 |
| UOPK | 12.2 | | | 11.7 | 11.9 | 11.9 | 11.9 | 11.9 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 11.8 |
| Molecular Weight (g/mol) | | | | 111 | 148 | 182 | 222 | 268 | 304 | 467 | 356 | 433 | 493 | 633 |
| Total Sulphur (% wt) | 0.56 | 0.002 | 0.005 | 0.008 | 0.021 | 0.066 | 0.191 | 0.434 | 0.63 | 1.40 | 0.86 | 1.16 | 1.36 | 1.95 |
| Mercaptan Sulphur (ppm) | 1.6 | 8.9 | 5.7 | 1.8 | 1.8 | 1.7 | 1.2 | | | | | | | |
| Total Nitrogen (ppm) | 953 | | | | | 2 | 12 | 91 | 242 | 2732 | 579 | 1274 | 2033 | 5325 |
| Basic Nitrogen (ppm) | 226.23 | | | | | 2.0463 | 10.229 | 36.862 | 71.512 | 641.29 | 147.06 | 302.25 | 474.58 | 1240.9 |
| Total Acid Number (mgKOH/g) | 0.05 | 0.00 | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.07 | 0.08 | 0.09 | 0.09 | 0.10 | 0.10 | 0.09 |
| Viscosity @ 20°C (cSt) | 4.88 | | | | 1.56 | | | | | | | | | |
| Viscosity @ 40°C (cSt) | 3.31 | | | | 1.14 | 1.79 | 3.10 | 5.91 | 10.1 | | | | | |
| Viscosity @ 50°C (cSt) | 2.80 | | | | | 1.53 | 2.56 | 4.66 | 7.63 | 293 | 16.5 | 60.6 | 219 | |
| Viscosity @ 60°C (cSt) | | | | | | | | | | 159 | 12.1 | 38.8 | 122 | |
| Viscosity @ 100°C (cSt) | | | | | | | | | | 26.8 | 4.48 | 10.3 | 22.5 | 838 |
| Viscosity @ 130°C (cSt) | | | | | | | | | | | | | | 154 |
| RON (Clear) | 31.1 | 77.5 | 61.9 | 59.0 | 39.1 | | | | | | | | | |
| MON (Clear) | 43.0 | 76.8 | 59.7 | 55.0 | 37.4 | | | | | | | | | |
| Paraffins (% wt) | 37.8 | 95.4 | 55.7 | 42.4 | 49.2 | | | | | | | | | |
| Naphthenes (%wt) | 32.2 | 4.6 | 42.5 | 38.5 | 28.2 | | | | | | | | | |
| Aromatics (% wt) | 30.0 | 0.0 | 1.8 | 19.0 | 22.6 | | | | | | | | | |
| Pour Point (°C) | -18 | | | | | -41 | -20 | 0 | 11 | 33 | 24 | 38 | 46 | 54 |
| Cloud Point (°C) | | | | | | -40 | -18 | 2 | | | | | | |
| Freeze Point (°C) | | | | | -59 | -37 | -15 | | | | | | | |
| Smoke Point (mm) | | | | | 26 | 24 | 22 | | | | | | | |
| Cetane Index | | | | | 44 | 49 | 56 | 62 | 66 | | | | | |
| Naphthalenes (% vol) | | | | | 0.0929 | 1.5399 | 5.1773 | 9.1977 | | | | | | |
| Aniline Point (°C) | | | | 52.6 | 57.6 | 65.0 | 72.2 | 79.3 | 84.2 | | 90.6 | 98.2 | 102.8 | |
| Hydrogen (% wt) | | 16.5 | 15.2 | 14.0 | 14.6 | 14.1 | 13.7 | 13.3 | 13.1 | | 12.7 | 12.3 | 12.1 | |
| Wax (% wt) | 8.2 | | | | | | | | | 16.4 | 21.8 | 21.1 | 18.6 | 9.2 |
| $C_7$ Asphaltenes (% wt) | 0.5 | | | | | | | | | 1.3 | | 0.0 | 0.0 | 3.4 |
| Micro Carbon Residue (% wt) | 1.7 | | | | | | | | | 5.0 | | 0.4 | 1.8 | 12.1 |
| Rams. Carbon Residue (% wt) | 1.5 | | | | | | | | | 4.5 | | 0.4 | 1.6 | 10.9 |
| Vanadium (ppm) | 18.6 | | | | | | | | | 54.3 | | 0.0 | 0.0 | 140.4 |
| Nickel (ppm) | 5.6 | | | | | | | | | 16.4 | | 0.0 | 0.0 | 42.5 |
| Iron (ppm) | 5.1 | | | | | | | | | 14.8 | | 0.0 | 0.0 | 38.3 |

Reference: **Crude 5**
Crude: **Crude 5**

# Crude Summary Report

| General Information | | Molecules (%wt on crude) | | Whole Crude Properties | |
|---|---|---|---|---|---|
| Reference: | Crude 5 | methane + ethane | 0.13 | Density @ 15°C (g/cc) | 0.783 |
| Name: | Crude 5. | propane | 0.64 | API Gravity | 49.18 |
| Traded Crude: | Unknown | isobutane | 0.42 | Total Sulphur (% wt) | 0.03 |
| Origin: | United States of A | n-butane | 1.26 | Pour Point (°C) | -26.83 |
| Sample Date: | - | isopentane | 0.55 | Viscosity @ 20°C (cSt) | 2.22 |
| Assay Date: | - | n-pentane | 0.61 | Viscosity @ 40°C (cSt) | 1.67 |
| Issue Date: | - | cyclopentane | 0.18 | Nickel (ppm) | 0.1 |
| Comments: | - | $C_6$ paraffins | 1.60 | Vanadium (ppm) | 0.0 |
| | | $C_6$ naphthenes | 3.20 | Total Nitrogen (ppm) | 88 |
| | | benzene | 0.24 | Total Acid Number (mgKOH/g) | 0.03 |
| | | $C_7$ paraffins | 6.21 | Mercaptan Sulphur (ppm) | 9.7 |
| | | $C_7$ naphthenes | 1.49 | Hydrogen Sulphide (ppm) | 0.0 |
| | | toluene | 0.47 | Reid Vapour Pressure (psi) | 8.0 |

| Cut Data | | Atmospheric Cuts | | | | | | | | | Vacuum Cuts | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Start (°C) | IBP | C5 | 65 | 100 | 150 | 200 | 250 | 300 | 350 | 370 | 370 | 450 | 500 | 550 |
| End (°C) | FBP | 65 | 100 | 150 | 200 | 250 | 300 | 350 | 370 | FBP | 450 | 500 | 550 | FBP |
| Yield (% wt) | | 2.9 | 11.1 | 17.4 | 13.2 | 11.4 | 10.2 | 8.4 | 2.9 | 20.0 | 9.8 | 4.5 | 3.0 | 2.7 |
| Yield (% vol) | | 3.5 | 12.0 | 18.4 | 13.5 | 11.1 | 9.7 | 7.8 | 2.7 | 17.7 | 8.8 | 4.0 | 2.6 | 2.3 |
| Cumulative Yield (% wt) | | 2.5 | 5.4 | 16.5 | 33.9 | 47.0 | 58.4 | 68.6 | 77.1 | 80.0 | 80.0 | 89.8 | 94.3 | 97.3 |
| Volume Average B.P. (°C) | 227 | 48 | 89 | 125 | 173 | 225 | 274 | 324 | 360 | 464 | 408 | 474 | 523 | 599 |
| Density @ 15°C (g/cc) | 0.783 | 0.653 | 0.723 | 0.740 | 0.764 | 0.797 | 0.823 | 0.845 | 0.858 | 0.885 | 0.871 | 0.883 | 0.896 | 0.930 |
| API Gravity | 49.2 | 85.3 | 64.2 | 59.6 | 53.6 | 45.9 | 40.3 | 35.8 | 33.3 | 28.3 | 30.9 | 28.7 | 26.3 | 20.6 |
| UOPK | 12.3 | | | 12.1 | 12.2 | 12.1 | 12.1 | 12.1 | 12.2 | 12.4 | 12.3 | 12.5 | 12.6 | 12.5 |
| Molecular Weight (g/mol) | | | | 116 | 148 | 183 | 223 | 270 | 307 | 420 | 361 | 446 | 512 | 607 |
| Total Sulphur (% wt) | 0.026 | 0.002 | 0.002 | 0.003 | 0.004 | 0.007 | 0.013 | 0.028 | 0.043 | 0.092 | 0.059 | 0.089 | 0.123 | 0.185 |
| Mercaptan Sulphur (ppm) | 9.7 | 1.2 | 5.0 | 7.9 | 11.5 | 12.7 | 10.3 | | | | | | | |
| Total Nitrogen (ppm) | 88 | | | | | 1 | 3 | 13 | 32 | 428 | 95 | 298 | 630 | 1641 |
| Basic Nitrogen (ppm) | 35.95 | | | | | 0.6897 | 2.3182 | 6.0011 | 10.711 | 173.83 | 24.95 | 75.812 | 193 | 861.8 |
| Total Acid Number (mgKOH/g) | 0.03 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.02 | 0.04 | 0.04 | 0.06 | 0.06 | 0.06 | 0.07 | 0.06 |
| Viscosity @ 20°C (cSt) | 2.22 | | | | 2.42 | | | | | | | | | |
| Viscosity @ 40°C (cSt) | 1.67 | | | | 1.74 | 2.68 | 4.21 | 6.99 | 10.4 | | | | | |
| Viscosity @ 50°C (cSt) | 1.48 | | | | | 2.26 | 3.48 | 5.56 | 8.03 | 32.4 | 13.8 | 35.6 | 93.2 | |
| Viscosity @ 60°C (cSt) | | | | | | | | | | 22.9 | 10.5 | 24.9 | 59.7 | |
| Viscosity @ 100°C (cSt) | | | | | | | | | | 7.82 | 4.39 | 8.31 | 15.6 | 60.1 |
| Viscosity @ 130°C (cSt) | | | | | | | | | | | | | | 23.0 |
| RON (Clear) | 37.9 | 78.7 | 59.1 | 57.3 | 38.8 | | | | | | | | | |
| MON (Clear) | 43.1 | 77.7 | 56.6 | 54.5 | 36.9 | | | | | | | | | |
| Paraffins (% wt) | 46.9 | 93.9 | 56.2 | 64.8 | 46.6 | | | | | | | | | |
| Naphthenes (%wt) | 33.3 | 6.1 | 41.7 | 22.4 | 29.3 | | | | | | | | | |
| Aromatics (% wt) | 19.7 | 0.0 | 2.1 | 12.8 | 24.1 | | | | | | | | | |
| Pour Point (°C) | -27 | | | | | -42 | -18 | 6 | 18 | 14 | 31 | 45 | 52 | -6 |
| Cloud Point (°C) | | | | | | -40 | -16 | 7 | | | | | | |
| Freeze Point (°C) | | | | | -60 | -35 | -12 | | | | | | | |
| Smoke Point (mm) | | | | | 27 | 21 | 16 | | | | | | | |
| Cetane Index | | | | | 51 | 56 | 62 | 68 | 74 | | | | | |
| Naphthalenes (% vol) | | | | | 0.1157 | 1.6315 | 4.8638 | 8.1883 | | | | | | |
| Aniline Point (°C) | | | | 48.1 | 55.7 | 68.2 | 80.2 | 92.2 | 100.7 | | 112.0 | 124.6 | 131.2 | |
| Hydrogen (% wt) | | 16.4 | 15.2 | 14.7 | 14.0 | 13.7 | 13.4 | 13.2 | 13.2 | | 13.2 | 13.1 | 13.0 | |
| Wax (% wt) | 8.2 | | | | | | | | | 25.9 | 28.0 | 29.3 | 24.5 | 13.7 |
| $C_7$ Asphaltenes (% wt) | 0.0 | | | | | | | | | 0.2 | | 0.0 | 0.0 | 1.4 |
| Micro Carbon Residue (% wt) | 0.1 | | | | | | | | | 0.6 | | 0.1 | 0.7 | 3.5 |
| Rams. Carbon Residue (% wt) | 0.1 | | | | | | | | | 0.5 | | 0.1 | 0.6 | 2.9 |
| Vanadium (ppm) | 0.0 | | | | | | | | | 0.2 | | 0.0 | 0.0 | 1.5 |
| Nickel (ppm) | 0.1 | | | | | | | | | 0.6 | | 0.0 | 0.0 | 4.4 |
| Iron (ppm) | 3.0 | | | | | | | | | 15.0 | | 0.0 | 0.0 | 111.8 |

# ATTACHMENT 2 – DETAILED EMISSION CALCULATIONS FOR CRUDE VAPOR SPECIATION

## Crude Vapor Speciation - Crude Profile 1

| Component | Liquid Molecular Weight ($M_l$) | Liquid Weight Percent ($W_i$) | Liquid Moles [1] ($W_i/M_l$) | Liquid Mole Fraction [2] $X_i = W_i/(M_t x M_l)$ | Temp (°F) 73.50 / Temp (°C) 23.06 / Antoine's Constants (deg. C) | | | Vapor Pressure [3] $P_i$* | Partial Pressure [4] $P_i = (P_i^*)(X_i)$ | Vapor Mole Fraction [5] $Y_i = (P_i/P_t)$ | Vapor Molecular Weight ($M_v$) | $(Y_i)(M_v)$ | Vapor Weight Percent [6] Yi (Mv/Mt) | Max Total HAP Vapor Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | A | B | C | | | | | | | |
| | (lb/lb-mole) | (wt%) | | (mole frac.) | | | | (psia) | (psia) | (mole frac.) | (lb/lb-mole) | | (wt%) | (wt%) |
| methane + ethane | 16.00 | 0.02% | 1.10E-05 | 2.05E-03 | 7.10 | 516.70 | 284.37 | 5031.02 | 10.34 | 0.45 | 16.00 | 7.21 | 20.22% | -- |
| propane | 44.10 | 0.21% | 4.79E-05 | 0.0089 | 6.86 | 819.30 | 248.73 | 134.86 | 1.20 | 0.05 | 44.10 | 2.31 | 6.48% | -- |
| isobutane | 58.12 | 0.20% | 3.44E-05 | 0.0064 | 6.82 | 912.10 | 243.34 | 48.03 | 0.31 | 0.01 | 58.12 | 0.78 | 2.18% | -- |
| n-butane | 58.12 | 1.15% | 1.98E-04 | 0.0369 | 6.73 | 909.70 | 237.00 | 32.61 | 1.20 | 0.05 | 58.12 | 3.05 | 8.54% | -- |
| isopentane | 72.15 | 1.18% | 1.64E-04 | 0.0305 | 6.79 | 1020.00 | 233.10 | 12.43 | 0.38 | 0.02 | 72.15 | 1.19 | 3.34% | -- |
| n-pentane | 72.15 | 1.70% | 2.35E-04 | 0.0438 | 6.86 | 1070.60 | 232.70 | 9.21 | 0.40 | 0.02 | 72.15 | 1.27 | 3.56% | -- |
| cyclopentane | 70.10 | 0.08% | 1.18E-05 | 2.19E-03 | 6.88 | 1119.20 | 230.74 | 5.68 | 1.25E-02 | 5.44E-04 | 70.10 | 3.81E-02 | 0.11% | -- |
| benzene | 78.11 | 0.22% | 2.77E-05 | 0.0052 | 6.91 | 1211.00 | 220.79 | 1.68 | 0.01 | 3.79E-04 | 78.11 | 0.03 | 0.08% | 0.15% |
| toluene | 92.14 | 0.61% | 6.65E-05 | 0.0124 | 7.02 | 1377.60 | 222.64 | 0.50 | 0.01 | 2.69E-04 | 92.14 | 0.02 | 0.07% | |
| crude oil | 207.00 | 94.63% | 4.57E-03 | 0.8517 | | | | 10.64 | 9.06 | 0.40 | 50.00 | 19.77 | 55.41% | -- |
| Total | | $M_t$ = | 0.005 | | | | | $P_t$ = | 22.92 | | $M_t$ = | 35.68 | 100.00% | |

**Sample Calcs for Benzene**

[1] Liquid Moles ($W_i/M_l$) = Benzene Liquid Weight Percent ($W_i$) (wt%) / Benzene Liquid Molecular Weight ($M_l$)(lb/lb-mole)

$$\text{Liquid Moles } (W_i/M_l) = \frac{0.22\%}{\frac{\text{lb-mole}}{78.11\ \text{lb}}} = 2.77\text{E-}05$$

[2] Liquid Mole Fraction ($X_i$) (mole frac.) = Liquid Moles of Benzene ($W_i/M_l$) / Total Liquid Moles (Mt)

$$\text{Liquid Mole Fraction } (X_i) \text{ (mole frac.)} = \frac{2.77\text{E-}05}{0.005} = 0.0052$$

[3] Vapor Pressure ($P_i$*) (psia) = 10^(A - (B/(C+Temp (deg. C))) x 14.7 psia / 760 mmHg

[4] Benzene Partial Pressure ($P_i$) (psia) = Benzene Vapor Pressure ($P_i$*) (psia) * Benzene Liquid Mole Fraction ($X_i$) (mole frac)

$$\text{Benzene Partial Pressure } (P_i) \text{ (psia)} = \frac{1.68\ \text{psia}}{\frac{0.0052}{}} = 0.01\ \text{psia}$$

[5] Benzene Vapor Mole Fraction ($Y_i$) (mole frac) = Benzene Partial Pressure ($P_i$) (psia) / Total Partial Pressure ($P_t$) (psia)

$$\text{Benzene Vapor Mole Fraction } (Y_i) \text{ (mole frac)} = \frac{0.01\ \text{psia}}{22.92\ \text{psia}} = 3.79\text{E-}04$$

[6] Benzene Vapor Weight Percent (wt%) = Vapor Mole Fraction (Yi) (mole frac.) x Vapor Molecular Weight (Mv) (lb/lb-mole) / Σ (Yi)(Mv)

$$\text{Vapor Weight Percent (wt\%)} = \frac{3.79\text{E-}04}{\frac{78.11\ \text{lb}}{\text{lb-mole}}} \times \frac{1}{35.68} = 0.08\%$$

## Crude Vapor Speciation - Crude Profile 2

| Component | Liquid Molecular Weight ($M_l$) | Liquid Weight Percent ($W_i$) | Liquid Moles [1] ($W_i/M_l$) | Liquid Mole Fraction [2] $X_i = W_i/(M_t x M_l)$ | Temp (°F) 73.50 / Temp (°C) 23.06 / Antoine's Constants (deg. C) A | B | C | Vapor Pressure [3] $P_i$* | Partial Pressure [4] $P_i = (P_i^*)(X_i)$ | Vapor Mole Fraction [5] $Y_i = (P_i/P_t)$ | Vapor Molecular Weight ($M_v$) | $(Y_i)(M_v)$ | Vapor Weight Percent [6] Yi (Mv/Mt) | Max Total HAP Vapor Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (lb/lb-mole) | (wt%) | | (mole frac.) | | | | (psia) | (psia) | (mole frac.) | (lb/lb-mole) | | (wt%) | (wt%) |
| methane + ethane | 16.00 | 0.00% | 2.10E-07 | 3.50E-05 | 7.10 | 516.70 | 284.37 | 5031.02 | 0.18 | 0.01 | 16.00 | 0.19 | 0.37% | -- |
| propane | 44.10 | 0.52% | 1.18E-04 | 0.0198 | 6.86 | 819.30 | 248.73 | 134.86 | 2.66 | 0.18 | 44.10 | 7.99 | 15.26% | -- |
| isobutane | 58.12 | 0.83% | 1.43E-04 | 0.0238 | 6.82 | 912.10 | 243.34 | 48.03 | 1.14 | 0.08 | 58.12 | 4.51 | 8.62% | -- |
| n-butane | 58.12 | 1.89% | 3.25E-04 | 0.0542 | 6.73 | 909.70 | 237.00 | 32.61 | 1.77 | 0.12 | 58.12 | 6.98 | 13.33% | -- |
| isopentane | 72.15 | 2.36% | 3.28E-04 | 0.0546 | 6.79 | 1020.00 | 233.10 | 12.43 | 0.68 | 0.05 | 72.15 | 3.33 | 6.36% | -- |
| n-pentane | 72.15 | 3.38% | 4.68E-04 | 0.0780 | 6.86 | 1070.60 | 232.70 | 9.21 | 0.72 | 0.05 | 72.15 | 3.53 | 6.73% | -- |
| cyclopentane | 70.10 | 0.00% | 6.53E-14 | 1.09E-11 | 6.88 | 1119.20 | 230.74 | 5.68 | 6.19E-11 | 4.21E-12 | 70.10 | 2.95E-10 | 0.00% | -- |
| benzene | 78.11 | 0.65% | 8.31E-05 | 0.0139 | 6.91 | 1211.00 | 220.79 | 1.68 | 0.02 | 1.59E-03 | 78.11 | 0.12 | 0.24% | 0.53% |
| toluene | 92.14 | 2.74% | 2.98E-04 | 0.0497 | 7.02 | 1377.60 | 222.64 | 0.50 | 0.02 | 1.68E-03 | 92.14 | 0.15 | 0.30% | |
| crude oil | 207.00 | 87.63% | 4.23E-03 | 0.7060 | | | | 10.64 | 7.51 | 0.51 | 50.00 | 25.54 | 48.79% | -- |
| Total | | $M_t$ = | 0.006 | | | | | $P_t$ = | 14.71 | | $M_t$ = | 52.35 | 100.00% | |

**Sample Calcs for Benzene**

[1] Liquid Moles ($W_i/M_l$) = Benzene Liquid Weight Percent ($W_i$) (wt%) / Benzene Liquid Molecular Weight ($M_l$)(lb/lb-mole)

$$\text{Liquid Moles } (W_i/M_l) = \frac{0.65\%}{\frac{\text{lb-mole}}{78.11\ \text{lb}}} = 8.31\text{E-}05$$

[2] Liquid Mole Fraction ($X_i$) (mole frac.) = Liquid Moles of Benzene ($W_i/M_l$) / Total Liquid Moles (Mt)

$$\text{Liquid Mole Fraction } (X_i) \text{ (mole frac.)} = \frac{8.31\text{E-}05}{0.006} = 0.0139$$

[3] Vapor Pressure ($P_i$*) (psia) = 10^(A - (B/(C+Temp (deg. C))) x 14.7 psia / 760 mmHg

[4] Benzene Partial Pressure ($P_i$) (psia) = Benzene Vapor Pressure ($P_i$*) (psia) * Benzene Liquid Mole Fraction ($X_i$) (mole frac)

$$\text{Benzene Partial Pressure } (P_i) \text{ (psia)} = \frac{1.68\ \text{psia}}{\frac{0.0139}{}} = 0.02\ \text{psia}$$

[5] Benzene Vapor Mole Fraction ($Y_i$) (mole frac) = Benzene Partial Pressure ($P_i$) (psia) / Total Partial Pressure ($P_t$) (psia)

$$\text{Benzene Vapor Mole Fraction } (Y_i) \text{ (mole frac)} = \frac{0.02\ \text{psia}}{14.71\ \text{psia}} = 1.59\text{E-}03$$

[6] Benzene Vapor Weight Percent (wt%) = Vapor Mole Fraction (Yi) (mole frac.) x Vapor Molecular Weight (Mv) (lb/lb-mole) / Σ (Yi)(Mv)

$$\text{Vapor Weight Percent (wt\%)} = \frac{1.59\text{E-}03}{\frac{78.11\ \text{lb}}{\text{lb-mole}}} \times \frac{1}{52.35} = 0.24\%$$

## Crude Vapor Speciation - Crude Profile 3

| Component | Liquid Molecular Weight ($M_l$) | Liquid Weight Percent ($W_i$) | Liquid Moles [1] ($W_i/M_l$) | Liquid Mole Fraction [2] $X_i = W_i/(M_t x M_l)$ | Temp ($^oF$) 73.50 / Temp ($^oC$) 23.06 / Antoine's Constants (deg. C) A | B | C | Vapor Pressure [3] $P_i$* | Partial Pressure [4] $P_i = (P_i^*)(X_i)$ | Vapor Mole Fraction [5] $Y_i = (P_i/P_t)$ | Vapor Molecular Weight ($M_v$) | $(Y_i)(M_v)$ | Vapor Weight Percent [6] Yi (Mv/Mt) | Max Total HAP Vapor Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (lb/lb-mole) | (wt%) | | (mole frac.) | A | B | C | (psia) | (psia) | (mole frac.) | (lb/lb-mole) | | (wt%) | (wt%) |
| methane + ethane | 16.00 | 0.03% | 1.93E-05 | 3.54E-03 | 7.10 | 516.70 | 284.37 | 5031.02 | 17.82 | 0.57 | 16.00 | 9.05 | 28.89% | -- |
| propane | 44.10 | 0.41% | 9.37E-05 | 0.0172 | 6.86 | 819.30 | 248.73 | 134.86 | 2.32 | 0.07 | 44.10 | 3.25 | 10.38% | -- |
| isobutane | 58.12 | 0.25% | 4.38E-05 | 0.0081 | 6.82 | 912.10 | 243.34 | 48.03 | 0.39 | 0.01 | 58.12 | 0.71 | 2.28% | -- |
| n-butane | 58.12 | 1.27% | 2.18E-04 | 0.0401 | 6.73 | 909.70 | 237.00 | 32.61 | 1.31 | 0.04 | 58.12 | 2.41 | 7.70% | -- |
| isopentane | 72.15 | 1.08% | 1.50E-04 | 0.0276 | 6.79 | 1020.00 | 233.10 | 12.43 | 0.34 | 0.01 | 72.15 | 0.79 | 2.51% | -- |
| n-pentane | 72.15 | 1.63% | 2.26E-04 | 0.0416 | 6.86 | 1070.60 | 232.70 | 9.21 | 0.38 | 0.01 | 72.15 | 0.88 | 2.80% | -- |
| cyclopentane | 70.10 | 0.05% | 7.29E-06 | 1.34E-03 | 6.88 | 1119.20 | 230.74 | 5.68 | 7.62E-03 | 2.42E-04 | 70.10 | 1.70E-02 | 0.05% | -- |
| benzene | 78.11 | 0.76% | 9.68E-05 | 0.0178 | 6.91 | 1211.00 | 220.79 | 1.68 | 0.03 | 9.50E-04 | 78.11 | 0.07 | 0.24% | 0.27% |
| toluene | 92.14 | 0.32% | 3.42E-05 | 0.0063 | 7.02 | 1377.60 | 222.64 | 0.50 | 0.00 | 9.92E-05 | 92.14 | 0.01 | 0.03% | |
| crude oil | 207.00 | 94.20% | 4.55E-03 | 0.8365 | | | | 10.64 | 8.90 | 0.28 | 50.00 | 14.13 | 45.12% | -- |
| Total | | $M_t$ = | 0.005 | | | | | $P_t$ = | 31.50 | | $M_t$ = | 31.32 | 100.00% | |

**Sample Calcs for Benzene**

[1] Liquid Moles ($W_i/M_l$) = Benzene Liquid Weight Percent ($W_i$) (wt%) / Benzene Liquid Molecular Weight ($M_l$)(lb/lb-mole)

$$\text{Liquid Moles } (W_i/M_l) = \frac{0.76\%}{78.11 \text{ lb}} \left| \frac{\text{lb-mole}}{} \right. = 9.68\text{E-}05$$

[2] Liquid Mole Fraction ($X_i$) (mole frac.) = Liquid Moles of Benzene ($W_i/M_l$) / Total Liquid Moles (Mt)

$$\text{Liquid Mole Fraction } (X_i) \text{ (mole frac.)} = \frac{9.68\text{E-}05}{0.005} = 0.0178$$

[3] Vapor Pressure ($P_i$*) (psia) = 10^(A - (B/(C+Temp (deg. C))) x 14.7 psia / 760 mmHg

[4] Benzene Partial Pressure ($P_i$) (psia) = Benzene Vapor Pressure ($P_i$*) (psia) * Benzene Liquid Mole Fraction ($X_i$) (mole frac)

$$\text{Benzene Partial Pressure } (P_i) \text{ (psia)} = \frac{1.68 \text{ psia}}{} \left| \frac{0.0178}{} \right. = 0.03 \text{ psia}$$

[5] Benzene Vapor Mole Fraction ($Y_i$) (mole frac) = Benzene Partial Pressure ($P_i$) (psia) / Total Partial Pressure ($P_t$) (psia)

$$\text{Benzene Vapor Mole Fraction } (Y_i) \text{ (mole frac)} = \frac{0.03 \text{ psia}}{31.50 \text{ psia}} = 9.50\text{E-}04$$

[6] Benzene Vapor Weight Percent (wt%) = Vapor Mole Fraction (Yi) (mole frac.) x Vapor Molecular Weight (Mv) (lb/lb-mole) / Σ (Yi)(Mv)

$$\text{Vapor Weight Percent (wt\%)} = \frac{9.50\text{E-}04}{} \left| \frac{78.11 \text{ lb}}{\text{lb-mole}} \right| \frac{1}{31.32} = 0.24\%$$

## Crude Vapor Speciation - Crude Profile 4

| Component | Liquid Molecular Weight ($M_l$) | Liquid Weight Percent ($W_i$) | Liquid Moles [1] ($W_i/M_l$) | Liquid Mole Fraction [2] $X_i = W_i/(M_t x M_l)$ | Temp (°F) 73.50 / Temp (°C) 23.06 / Antoine's Constants (deg. C) A | B | C | Vapor Pressure [3] $P_i$* | Partial Pressure [4] $P_i = (P_i^*)(X_i)$ | Vapor Mole Fraction [5] $Y_i = (P_i/P_t)$ | Vapor Molecular Weight ($M_v$) | $(Y_i)(M_v)$ | Vapor Weight Percent [6] Yi (Mv/Mt) | Max Total HAP Vapor Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (lb/lb-mole) | (wt%) | | (mole frac.) | A | B | C | (psia) | (psia) | (mole frac.) | (lb/lb-mole) | | (wt%) | (wt%) |
| methane + ethane | 16.00 | 0.02% | 1.26E-05 | 2.29E-03 | 7.10 | 516.70 | 284.37 | 5031.02 | 11.50 | 0.45 | 16.00 | 7.24 | 20.42% | -- |
| propane | 44.10 | 0.43% | 9.65E-05 | 0.0175 | 6.86 | 819.30 | 248.73 | 134.86 | 2.36 | 0.09 | 44.10 | 4.09 | 11.55% | -- |
| isobutane | 58.12 | 0.39% | 6.73E-05 | 0.0122 | 6.82 | 912.10 | 243.34 | 48.03 | 0.59 | 0.02 | 58.12 | 1.34 | 3.78% | -- |
| n-butane | 58.12 | 1.49% | 2.57E-04 | 0.0466 | 6.73 | 909.70 | 237.00 | 32.61 | 1.52 | 0.06 | 58.12 | 3.47 | 9.80% | -- |
| isopentane | 72.15 | 1.08% | 1.50E-04 | 0.0272 | 6.79 | 1020.00 | 233.10 | 12.43 | 0.34 | 0.01 | 72.15 | 0.96 | 2.71% | -- |
| n-pentane | 72.15 | 1.67% | 2.32E-04 | 0.0420 | 6.86 | 1070.60 | 232.70 | 9.21 | 0.39 | 0.02 | 72.15 | 1.10 | 3.10% | -- |
| cyclopentane | 70.10 | 0.22% | 3.13E-05 | 5.67E-03 | 6.88 | 1119.20 | 230.74 | 5.68 | 3.22E-02 | 1.27E-03 | 70.10 | 8.88E-02 | 0.25% | -- |
| benzene | 78.11 | 0.15% | 1.96E-05 | 0.0035 | 6.91 | 1211.00 | 220.79 | 1.68 | 0.01 | 2.35E-04 | 78.11 | 0.02 | 0.05% | 0.19% |
| toluene | 92.14 | 1.37% | 1.49E-04 | 0.0269 | 7.02 | 1377.60 | 222.64 | 0.50 | 0.01 | 5.27E-04 | 92.14 | 0.05 | 0.14% | |
| crude oil | 207.00 | 93.17% | 4.50E-03 | 0.8161 | | | | 10.64 | 8.69 | 0.34 | 50.00 | 17.08 | 48.21% | -- |
| Total | | $M_t$ = | 0.006 | | | | | $P_t$ = | 25.42 | | $M_t$ = | 35.44 | 100.00% | |

**Sample Calcs for Benzene**

[1] Liquid Moles ($W_i/M_l$) = Benzene Liquid Weight Percent ($W_i$) (wt%) / Benzene Liquid Molecular Weight ($M_l$)(lb/lb-mole)

$$\text{Liquid Moles } (W_i/M_l) = \frac{0.15\% \mid \text{lb-mole}}{78.11 \text{ lb}} = 1.96\text{E-}05$$

[2] Liquid Mole Fraction ($X_i$) (mole frac.) = Liquid Moles of Benzene ($W_i/M_l$) / Total Liquid Moles (Mt)

$$\text{Liquid Mole Fraction } (X_i) \text{ (mole frac.)} = \frac{1.96\text{E-}05}{0.006} = 0.0035$$

[3] Vapor Pressure ($P_i$*) (psia) = 10^(A - (B/(C+Temp (deg. C))) x 14.7 psia / 760 mmHg

[4] Benzene Partial Pressure ($P_i$) (psia) = Benzene Vapor Pressure ($P_i$*) (psia) * Benzene Liquid Mole Fraction ($X_i$) (mole frac)

$$\text{Benzene Partial Pressure } (P_i) \text{ (psia)} = \frac{1.68 \text{ psia} \mid 0.0035}{} = 0.01 \text{ psia}$$

[5] Benzene Vapor Mole Fraction ($Y_i$) (mole frac) = Benzene Partial Pressure ($P_i$) (psia) / Total Partial Pressure ($P_t$) (psia)

$$\text{Benzene Vapor Mole Fraction } (Y_i) \text{ (mole frac)} = \frac{0.01 \text{ psia}}{25.42 \text{ psia}} = 2.35\text{E-}04$$

[6] Benzene Vapor Weight Percent (wt%) = Vapor Mole Fraction (Yi) (mole frac.) x Vapor Molecular Weight (Mv) (lb/lb-mole) / Σ (Yi)(Mv)

$$\text{Vapor Weight Percent (wt\%)} = \frac{2.35\text{E-}04 \mid 78.11 \text{ lb} \mid 1}{\text{lb-mole} \mid 35.44} = 0.05\%$$

## Crude Vapor Speciation - Crude Profile 5

| Component | Liquid Molecular Weight ($M_l$) | Liquid Weight Percent ($W_i$) | Liquid Moles [1] ($W_i/M_l$) | Liquid Mole Fraction [2] $X_i = W_i/(M_t x M_l)$ | Temp (°F) 73.50 / Temp (°C) 23.06 / Antoine's Constants (deg. C) | | | Vapor Pressure [3] $P_i^*$ | Partial Pressure [4] $P_i = (P_i^*)(X_i)$ | Vapor Mole Fraction [5] $Y_i = (P_i/P_t)$ | Vapor Molecular Weight ($M_v$) | $(Y_i)(M_v)$ | Vapor Weight Percent [6] Yi (Mv/Mt) | Max Total HAP Vapor Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (lb/lb-mole) | (wt%) | | (mole frac.) | A | B | C | (psia) | (psia) | (mole frac.) | (lb/lb-mole) | | (wt%) | (wt%) |
| methane + ethane | 16.00 | 0.13% | 8.06E-05 | 1.49E-02 | 7.10 | 516.70 | 284.37 | 5031.02 | 75.15 | 0.83 | 16.00 | 13.33 | 61.44% | -- |
| propane | 44.10 | 0.64% | 1.45E-04 | 0.0269 | 6.86 | 819.30 | 248.73 | 134.86 | 3.63 | 0.04 | 44.10 | 1.77 | 8.17% | -- |
| isobutane | 58.12 | 0.42% | 7.25E-05 | 0.0134 | 6.82 | 912.10 | 243.34 | 48.03 | 0.65 | 0.01 | 58.12 | 0.42 | 1.92% | -- |
| n-butane | 58.12 | 1.26% | 2.16E-04 | 0.0401 | 6.73 | 909.70 | 237.00 | 32.61 | 1.31 | 0.01 | 58.12 | 0.84 | 3.88% | -- |
| isopentane | 72.15 | 0.55% | 7.62E-05 | 0.0141 | 6.79 | 1020.00 | 233.10 | 12.43 | 0.18 | 0.00 | 72.15 | 0.14 | 0.65% | -- |
| n-pentane | 72.15 | 0.61% | 8.49E-05 | 0.0157 | 6.86 | 1070.60 | 232.70 | 9.21 | 0.14 | 0.00 | 72.15 | 0.12 | 0.53% | -- |
| cyclopentane | 70.10 | 0.18% | 2.54E-05 | 4.71E-03 | 6.88 | 1119.20 | 230.74 | 5.68 | 2.67E-02 | 2.96E-04 | 70.10 | 2.08E-02 | 0.10% | -- |
| benzene | 78.11 | 0.24% | 3.04E-05 | 0.0056 | 6.91 | 1211.00 | 220.79 | 1.68 | 0.01 | 1.05E-04 | 78.11 | 0.01 | 0.04% | 0.06% |
| toluene | 92.14 | 0.47% | 5.15E-05 | 0.0096 | 7.02 | 1377.60 | 222.64 | 0.50 | 0.00 | 5.26E-05 | 92.14 | 0.00 | 0.02% | |
| crude oil | 207.00 | 95.50% | 4.61E-03 | 0.8549 | | | | 10.64 | 9.10 | 0.10 | 50.00 | 5.04 | 23.25% | -- |
| Total | | $M_t$ = | 0.005 | | | | | $P_t$ = | 90.19 | | $M_t$ = | 21.70 | 100.00% | |

**Sample Calcs for Benzene**

[1] Liquid Moles ($W_i/M_l$) = Benzene Liquid Weight Percent ($W_i$) (wt%) / Benzene Liquid Molecular Weight ($M_l$)(lb/lb-mole)

$$\text{Liquid Moles } (W_i/M_l) = \frac{0.24\%}{\frac{\text{lb-mole}}{78.11\ \text{lb}}} = 3.04\text{E-}05$$

[2] Liquid Mole Fraction ($X_i$) (mole frac.) = Liquid Moles of Benzene ($W_i/M_l$) / Total Liquid Moles (Mt)

$$\text{Liquid Mole Fraction } (X_i) \text{ (mole frac.)} = \frac{3.04\text{E-}05}{0.005} = 0.0056$$

[3] Vapor Pressure ($P_i^*$) (psia) = 10^(A - (B/(C+Temp (deg. C))) x 14.7 psia / 760 mmHg

[4] Benzene Partial Pressure ($P_i$) (psia) = Benzene Vapor Pressure ($P_i^*$) (psia) * Benzene Liquid Mole Fraction ($X_i$) (mole frac)

$$\text{Benzene Partial Pressure } (P_i) \text{ (psia)} = \frac{1.68\ \text{psia}}{\frac{0.0056}{}} = 0.01\ \text{psia}$$

[5] Benzene Vapor Mole Fraction ($Y_i$) (mole frac) = Benzene Partial Pressure ($P_i$) (psia) / Total Partial Pressure ($P_t$) (psia)

$$\text{Benzene Vapor Mole Fraction } (Y_i) \text{ (mole frac)} = \frac{0.01\ \text{psia}}{90.19\ \text{psia}} = 1.05\text{E-}04$$

[6] Benzene Vapor Weight Percent (wt%) = Vapor Mole Fraction (Yi) (mole frac.) x Vapor Molecular Weight (Mv) (lb/lb-mole) / Σ (Yi)(Mv)

$$\text{Vapor Weight Percent (wt\%)} = \frac{1.05\text{E-}04}{\frac{78.11\ \text{lb}}{\text{lb-mole}}} \cdot \frac{1}{21.70} = 0.04\%$$

# Texas Gulf Terminals Inc.
# Fugitives for the SPM System (DWP Emissions Source for PSD Applicability)
# Emission Calculations

Maximum w/ Contingency (days per year)

| | |
|---|---|
| 365 | days |
| 24 | hr/day |

Emission Calculations [1]

| Component Type | Total Number of Components [1] | Oil & Gas Emission Factor Type (lb/hr) | Fugitive Emission Factor [2] (lb/hr/ component) | Total Organic Compound lbs/hr | Total Organic Compound lbs/day | Total Organic Compound tons/project | Avg. Methane Vapor Weight % [5] | Methane Emissions [6] tons/project | $CO_2e$ Emissions [7] tons/project |
|---|---|---|---|---|---|---|---|---|---|
| Valves | 8 | Light Liquid (Light Oil > 20° API) | 5.50E-03 | 4.40E-02 | 1.06 | 0.19 | 26% | 0.05 | 1.25 |
| Flanges | 26 | Light Liquid (Light Oil > 20° API) | 2.43E-04 | 6.32E-03 | 0.15 | 2.77E-02 | 26% | 0.01 | 0.18 |
| | **Total TOC [4] - Heavy Oil Streams** | | | **0.05** | **1.21** | **0.22** | **--** | **0.06** | **1.43** |

Notes:

[1] Component counts are based on Engineering design information provided by Lloyd Engineering to Trinity Consultants on April 12, 2018.

[2] Emission Factors were obtained from *Table 4. Average Emission Factors - Petroleum Industry* (Oil & Gas Production Operations) of TCEQ's Addendum to RG-360A, Emission Factors for Equipment Leak Fugitives Components, January 2008.

[3] Fugitive emissions are conservatively estimated to be 100% VOC.

[4] Annual operating hours are conservatively assumed to be 8,760 hours per year.

[5] Methane vapor weight fraction is based on crude composition data.

[6] Methane Annual Emissions (tpy) = Max Methane % in Crude/Condensate Vapors x TOC Annual Emissions (tpy)

$$\text{Methane Annual Emissions from Valves (tpy)} = \frac{26\%}{} \left| \frac{0.19 \text{ tons}}{\text{yr}} \right. = 0.05 \text{ tpy}$$

[7] Global Warming Potential (GWP) of 25 for methane obtained from Appendix Table A-1 of 40 CFR Part 98.

$$CO_2e \text{ Annual Emissions from Valves (tpy)} = \frac{0.05 \text{ tons}}{\text{yr}} \left| \frac{25}{} \right. = 1.25 \text{ tpy}$$

# ATTACHMENT 3 – GHG EMISSIONS CALCULATION FOR MARINE LOADING AND SPM FUGITIVES

**Texas Gulf Terminals Inc.**

**Normal Operations Emissions Summary - Crude Carrier, Support Vessels & boats**

**Annual Emissions Summary (tons/year)**

| Emission Unit ID | Emission Unit | NSR Regulated Air Pollutants & Greenhouse Gas Emissions ($CO_2e$) | | | | | | | | | | | Hazardous Air Pollutants (HAPs) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | PM | $PM_{10}$ | $PM_{2.5}$ | $NO_x$ | $SO_2$ | $H_2SO_4$ | CO | VOC | $H_2S$ | Pb | $CO_2e$ | Total VOC HAPs |
| | | tons/yr | tons/yr | tons/yr | tons/yr | tons/yr | tons/yr | tons/yr | tons/yr | tons/yr | tons/yr | tons/yr | tons/yr |
| **DWP Emissions Source for PSD Applicability** | | | | | | | | | | | | | |
| Marine Loading | Marine Loading | | | | | | | | 10,808 | 0.24 | | 70,251 | 2.00E+02 |
| SPM Fugitive | SPM Fugitive | | | | | | | | 0.22 | | | 1 | |
| **Indirect Emission Sources** | | | | | | | | | | | | | |
| Tug Boat - Supply Boat Main Engines | Tug Boat - Supply Boat Main Engines | 9.94 | 5.70 | 5.53 | 183.29 | 10.62 | 3.32E-01 | 78.14 | 9.11 | | 2.88E-03 | 16,271 | 1.69E-01 |
| Tug Boat Aux Engine | Tug Boat Aux Engine | 0.21 | 0.21 | 0.21 | 4.69 | 0.32 | 1.01E-02 | 3.55 | 1.09 | | 8.77E-05 | 495 | 1.20E-02 |
| Pilot Boats | Pilot Boats | 0.91 | 0.52 | 0.50 | 4.28 | 0.97 | 3.03E-02 | 7.13 | 0.83 | | 2.63E-04 | 1,484 | 1.55E-02 |
| Helicopter | Helicopter | 0.00 | 0.00 | 0.00 | 0.05 | 0.01 | 0.00E+00 | 0.14 | 0.10 | | 0.00E+00 | 11 | 6.90E-02 |
| Carrier Main Engine | Carrier Main Engine | 27.57 | 27.57 | 25.34 | 728.02 | 16.95 | 5.29E-01 | 65.95 | 14.54 | | 4.60E-03 | 25,955 | 2.70E-01 |
| Carrier Aux Engine | Carrier Aux Engine | 4.67 | 2.68 | 2.60 | 110.26 | 4.99 | 1.56E-01 | 36.71 | 4.28 | | 1.35E-03 | 5,096 | 5.31E-02 |
| Crane Engine | Crane Engine | 2.21 | 1.27 | 1.23 | 51.06 | 2.36 | 7.37E-02 | 17.36 | 2.03 | | 6.41E-04 | 3,615 | 3.77E-02 |
| Carrier Boiler | Carrier Boiler | 8.09 | 8.09 | 8.09 | 58.83 | 34.81 | 0.00E+00 | 12.26 | 0.49 | | 3.09E-03 | 56,146 | 1.69E-01 |
| Cargo Pumps | Cargo Pumps | 10.89 | 6.24 | 6.05 | 373.25 | 11.63 | 3.63E-01 | 85.54 | 9.98 | | 3.16E-03 | 17,812 | 1.86E-01 |
| Stripping Pumps | Stripping Pumps | 0.29 | 0.17 | 0.16 | 9.95 | 0.31 | 9.69E-03 | 2.28 | 0.27 | | 8.42E-05 | 475 | 4.95E-03 |
| Ballast Pumps | Ballast Pumps | 4.35 | 2.50 | 2.42 | 149.30 | 4.65 | 1.45E-01 | 34.21 | 3.99 | | 1.26E-03 | 7,125 | 7.42E-02 |
| **TOTAL Normal Operation Scenario (Worst Case)** | | **69.1** | **54.9** | **52.1** | **1673.0** | **87.6** | **1.65E+00** | **343.3** | **10,855** | **0.24** | **1.74E-02** | **134,484** | **201.1** |

# Texas Gulf Terminals Inc.
## Normal Operations Emission Calculations
### Marine Loading (DWP Emissions Source for PSD Applicability)
### Greenhouse Gas Emissions

| Parameter | Value | Unit |
|---|---|---|
| Avg. methane vapor weight % in Crude Oil [1] | 26% | |

[1] Methane vapor weight fraction is based on crude composition data.

| Pollutant | Liquid Loaded [1] | TOC Annual Emissions (tpy) | Annual Emissions [2],[3] (tpy) |
|---|---|---|---|
| Methane | Crude Oil | 10,365 | 2,695 |
| | Condensate | 10,808 | 2,810 |
| $CO_2e$ | Crude Oil | -- | 67,372 |
| | Condensate | -- | 70,251 |

[1] For annual emission estimates, the worst-case marine loading commodity between Crude oil and Condensate will be utilized.

[2] Methane Annual Emissions (tpy) = Max Methane % in Crude/Condensate Vapors x TOC Annual Emissions (tpy)

$$\text{Methane Annual Emissions from Crude Oil (tpy)} = 26\% \times \frac{10{,}365 \text{ tons}}{\text{yr}} = 2{,}695 \text{ tpy}$$

[3] Global Warming Potential (GWP) of 25 for methane obtained from Appendix Table A-1 of 40 CFR Part 98.

$$CO_2e \text{ Annual Emissions from Crude Oil (tpy)} = \frac{2{,}695 \text{ tons}}{\text{yr}} \times 25 = 67{,}372 \text{ tpy}$$

# Texas Gulf Terminals Inc.
# Fugitives for the SPM System (DWP Emissions Source for PSD Applicability)
# Emission Calculations

Maximum w/ Contingency (days per year)

| | |
|---|---|
| 365 | days |
| 24 | hr/day |

Emission Calculations [1]

| Component Type | Total Number of Components [1] | Oil & Gas Emission Factor Type (lb/hr) | Fugitive Emission Factor [2] (lb/hr/ component) | Total Organic Compound lbs/hr | Total Organic Compound lbs/day | Total Organic Compound tons/project | Avg. Methane Vapor Weight % [5] | Methane Emissions [6] tons/project | $CO_2e$ Emissions [7] tons/project |
|---|---|---|---|---|---|---|---|---|---|
| Valves | 8 | Light Liquid (Light Oil > 20° API) | 5.50E-03 | 4.40E-02 | 1.06 | 0.19 | 26% | 0.05 | 1.25 |
| Flanges | 26 | Light Liquid (Light Oil > 20° API) | 2.43E-04 | 6.32E-03 | 0.15 | 2.77E-02 | 26% | 0.01 | 0.18 |
| | **Total TOC [4] - Heavy Oil Streams** | | | **0.05** | **1.21** | **0.22** | **--** | **0.06** | **1.43** |

Notes:

[1] Component counts are based on Engineering design information provided by Lloyd Engineering to Trinity Consultants on April 12, 2018.

[2] Emission Factors were obtained from *Table 4. Average Emission Factors - Petroleum Industry* (Oil & Gas Production Operations) of TCEQ's Addendum to RG-360A, Emission Factors for Equipment Leak Fugitives Components, January 2008.

[3] Fugitive emissions are conservatively estimated to be 100% VOC.

[4] Annual operating hours are conservatively assumed to be 8,760 hours per year.

[5] Methane vapor weight fraction is based on crude composition data.

[6] Methane Annual Emissions (tpy) = Max Methane % in Crude/Condensate Vapors x TOC Annual Emissions (tpy)

$$\text{Methane Annual Emissions from Valves (tpy)} = 26\% \left| \frac{0.19 \text{ tons}}{\text{yr}} \right. = 0.05 \text{ tpy}$$

[7] Global Warming Potential (GWP) of 25 for methane obtained from Appendix Table A-1 of 40 CFR Part 98.

$$CO_2e \text{ Annual Emissions from Valves (tpy)} = \frac{0.05 \text{ tons}}{\text{yr}} \left| 25 \right. = 1.25 \text{ tpy}$$

# ATTACHMENT 4 – COMPARISON OF CRUDE/CONDENSATE EMISSIONS BETWEEN EQUATIONS 1 AND 2 OF AP-42 CHAPTER 5.2

A comparison of emissions between Equations 1 and 2 of AP-42 Chapter 5.2 for crude oil and condensate is shown in the table below.

| Liquid Loaded [1] | Loading Calculation | Compartment Condition Prior to Loadng | Saturation Factor [2] | Maximum Temp [3] | | Vapor MW | Maximum True Vapor Pressure (TVP) [4] | Arrival Emission Factor [5] | Generated Emission Factor [6] | Uncontrolled Loading Loss [7] | TOC to VOC Factor | Hourly Loading Rate [8] | Uncontrolled VOC Hourly Emissions [9] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (˚F) | (˚R) | (lb/lb mol) | (psia) | (lb/1,000 gal) | (lb/1,000 gal) | (lb/1,000 gal) | | (bbl/hr) | (lb/hr) |
| Crude Oil | AP-42 Ch 5.2, Eq 1 - API | Volatile Uncleaned | 0.2 | 73.5 | 533.2 | 50 | 11 | -- | -- | 2.57 | 1 | 60,000 | 6,478.07 |
| Crude Oil | AP-42 Ch 5.2, Eq 2-3 | Volatile Uncleaned | -- | 73.5 | 533.2 | 50 | 11 | 0.86 | 0.78 | 1.64 | 0.85 | 60,000 | 3,508.46 |
| Condensate | AP-42 Ch 5.2, Eq 1 - API | Volatile Uncleaned | 0.2 | 73.5 | 533.2 | 60 | 11 | -- | -- | 3.08 | 1 | 60,000 | 7,773.68 |
| Condensate | AP-42 Ch 5.2, Eq 2-3 | Volatile Uncleaned | -- | 73.5 | 533.2 | 60 | 11 | 0.86 | 0.93 | 1.79 | 0.85 | 60,000 | 3,841.73 |

*[1] For hourly emission estimates, the worst-case marine loading commodity between Crude oil and Condensate will be utilized.*
*[2] Saturation factor for marine loading obtained from U.S. EPA 42, Section 5.2 (1/95), Table 5.2-1.*
*[3] Maximum of monthly average liquid surface temperature was used.*
*[4] Maximum true vapor pressure for Crude oil and Condensate obtained from information provided by Texas Gulf Terminals*
*[5] Arrival emission factor for crude/condensate loading obtained from U.S. EPA 42, Section 5.2 (1/95), Table 5.2-3.*
*[6] Generated emission factor is calculated using Equation 3 from U.S. EPA 42, Section 5.2 (1/95).*
*[7] Uncontrolled Loading Loss (lb/1,000 gal) = 12.46 x Saturation Factor x Maximum TVP of Liquid Loaded (psia) x Vapor MW (lb/lbmol) / Maximum Temperature of Bulk Liquid Loaded (°R)*
*[8] Hourly Loading Rate obtained from information provided by TGTI Revised Design Parameters email from Ms. Denise Rogers (TGTI) to Mr. Brian Burdorf (Trinity Consultants) on February 25, 2018.*
*[9] Uncontrolled VOC Hourly Emissions (lb/hr) = Uncontrolled Loading Loss (lb/1,000 gal) x Hourly Loading Rate (bbl/hr) x 42 gal/bbl x TOC to VOC Factor x (1/1,000)*

# ATTACHMENT 5 – REFERENCE FOR EQUATION 3 OF AP-42 CHAPTER 5.2

API Manual of Petroleum Measurement Standards
Chapter 19.5
(Formerly, API Publication 2514A)

EI Hydrocarbon Management
HM 65

# Atmospheric hydrocarbon emissions from marine vessel transfer operations

1st edition, September 2009

API MPMS Chapter 19.5/EI HM 65

# Atmospheric hydrocarbon emissions from marine vessel transfer operations

First Edition

September 2009

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## Foreword

This publication was prepared jointly by the American Petroleum Institute Committee on Petroleum Measurement and the Energy Institute Hydrocarbon Management Committee. This standard supersedes API Publication 2514A, Second Edition, September 1981, which is withdrawn. See A.1 for more information on the previous editions of this document.

The American Petroleum Institute Committee on Petroleum Measurement (COPM) and the Energy Institute's Hydrocarbon Management Committee (HMC) are responsible for the production and maintenance of standards and guides covering various aspects of static and dynamic measurement of petroleum. The API/EI Joint Committee on Hydrocarbon Management (JCHM), its sub-committees and work groups consist of technical specialists representing oil companies, equipment manufacturers, service companies, terminal and ship owners and operators. The API/EI JCHM encourages international participation and when producing publications its aim is to represent the best consensus of international technical expertise and good practice. This is the main reason behind the production of joint publications involving cooperation with experts from both the API and EI.

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## Contents

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# Atmospheric hydrocarbon emissions from marine vessel transfer operations

## 1 Scope

This standard provides methods for estimating evaporative loss from marine vessel transfer operations. Specifically, this standard addresses:

1) loading stock into:

    a) ship or ocean barges, or

    b) shallow draft barges, and

2) loading ballast water into ship or ocean barges from which crude oil has been unloaded.

The emission estimates are for uncontrolled loading operations and do not apply to operations using vapor balance or vapor control systems or ballasting of ships with segregated ballast tanks.

This standard does not address evaporative loss for:

1) very large crude carriers (VLCCs) or ultra large crude carriers (ULCCs) (unless the saturation factor $K_S$ is determined);

2) marine vessels employing crude oil washing (see 3.3.1);

3) marine vessel transit loss;

4) loading ballast water into marine vessels that, prior to dockside unloading, held anything other than crude oil (unless the saturation factor $K_S$ is determined); or

5) unloading marine vessels.

This standard supersedes API 2514A, Second Edition, September 1981, which is withdrawn.

## 2 References


[1] American Petroleum Institute, *Recommended Practice for Specification of Evaporative Losses*, *Manual of Petroleum Measurement Standards*, Chapter 19, Section 4, Second Edition, September 2005

[2] American Petroleum Institute, Publication 2524, *Impact Assessment of New Data on the Validity of American Petroleum Institute Marine Transfer Operation Emission Factors*, July 1992

[3] American Petroleum Institute, Publication 2514A, *Atmospheric Hydrocarbon Emissions from Marine Vessel Transfer Operations*, Second Edition, September 1981

[4] Spectrasyne Ltd., “Studies of VOC Emissions from External Floating Roof Tanks and Barge Loading—November 1993,” Spectrasyne Report No. TR9413, prepared for CONCAWE, Brussels, Belgium, June 13, 1994

[5] CONCAWE, “VOC Emissions from External Floating Roof Tanks: Comparison of Remote Measurements by Laser with Calculated Methods,” CONCAWE Report No. 95/52, January 1995